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Potato Refuse Piles as a Factor in the Dissemination of Late Blight

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BULLETIN 416

POTATO REFUSE PILES AS A FACTOR IN THE DISSEMINATION OF LATE BLIGHT

REINER BONDE[1] AND E. S. SCHULTZ[2]

INTRODUCTION

Experiments pertaining to the control of late blight caused by *Phytophthora infestans* (Mont.) de Bary have been conducted in Maine for 50 years. However, the control of this disease is still an important problem in this State and elsewhere. Late blight or "rust," as it is commonly called in Maine, occurs every year in the

FIG. 1. Typical potato refuse pile near a storage house. Many potato plants severely infected with late blight or "Rust" were found growing on this refuse pile. Such infected refuse piles are the principal sources of late blight infection in Maine.

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concentrated potato area of Aroostook County, and the annual loss varies from 2 to 15 per cent of the total crop.

Maine potato farmers purchase about 7,000,000 pounds of copper fungicides annually, and spend at least $1,000,000 a year for spraying and dusting potatoes for the control of late blight. In spite of this extensive spraying program, the annual loss caused by late blight in Maine is nearly 4,000,000 bushels or about 9 per cent of the total crop of the State.

Much time and effort have been devoted in Maine to studies pertaining to the problem of spraying or dusting for the control of late blight. In recent years it has seemed desirable to secure more detailed information about the primary sources of this disease and the factors which aid in its dissemination.

This paper summarizes the authors' attempts to determine the primary sources of late-blight infection in Maine. The results demonstrate the important role that the potato refuse or cull pile may have in the dissemination of this disease.

PREVIOUS STUDIES REGARDING OVERWINTERING OF *PHYTOPHTHORA INFESTANS*

Melhus (11)[3] in 1915, working in Aroostook County, Maine, showed that the late-blight mycelium is perennial and may grow from the diseased seed tuber up the stems to the surface of the soil, sporulate, and thereby cause infection on the foliage. He, however, points out that only a small proportion of the diseased tubers function in this way and that environmental factors and the state of germination of the tuber play a very important part. According to Melhus (11, pp. 71-72), Berkeley in 1846 was probably the first to suggest that the mycelium of *P. infestans* overwinters in the potato tuber. He also states that Berkeley's perennial-mycelium theory was later first confirmed experimentally by de Bary in 1861, and by Jensen in 1887. Melhus (11, pp. 71-72 and 93) mentions 12 investigators who failed to show that the late-blight fungus is perennial in the seed tubers; and de Bary, according to Murphy and McKay (12, p. 418), failed for 15 years to confirm his theory regarding the perennial nature of the fungus.

[3] Reference is made by number to "Literature Cited" on p. 246.

Murphy and McKay (12) in 1927 reported two cases in which diseased shoots produced by blighted tubers planted in the open reached the surface of the ground and led to aerial infection. They state that only four other investigators since de Bary's work in 1861 have shown that epidemics can occur from diseased seed pieces, namely, Jensen in 1887, Pethybridge in 1911, Melhus in 1913 and 1915, and lastly Salmon and Ware in 1926. They mention the fact that 14 other investigators had failed to confirm the above positive results.

It has been assumed by the present authors and by potato growers that the primary infection in the field generally originates from diseased seed tubers which are planted in the field. In Maine, however, it has been very difficult to find actual cases where late-blight epidemics have been started from this source. Many commercial fields were examined over a period of 10 years or more in attempts to find specific examples where late-blight epidemics have been started by planting dry-rot seed tubers. So far only one case has been noted.

ATTEMPTS TO CREATE EPIDEMICS BY PLANTING DRY-ROT SEED TUBERS

The authors attempted also to create late-blight epidemics by actually planting infected seed potatoes in a number of fields. The development of the disease was carefully observed for the six-year period from 1935 to 1940. It was surprising to find that very few of the diseased seed pieces developed infected plants. Many of the diseased seed pieces decayed rapidly when planted in the soil and no late blight or very little resulted. The data are given in Table 1.

The data in Table 1 show that of the 1,410 diseased seed pieces planted in the field only four produced diseased shoots that appeared above the surface of the soil. None of the diseased plants started an epidemic and the infected sprouts soon died.

During the past two seasons an experimental plot was planted at Presque Isle, Maine, with late-blight-infected tubers. The decayed parts, due to other organisms, were carefully removed to inhibit decay of these tubers before the diseased shoots reached the top of the soil. The results of these tests disclosed that 4 per cent

TABLE 1

Infected plants resulting from planting dry-rot tubers in the field

Year	Number diseased tubers planted	Number plants emerging	Number infected plants
1935	206	20	1 diseased shoot
1936	250	23	0
1937	206	19	0
1938	400	89	2 diseased shoots
1939	200	54	1 diseased shoot
1940	150	15	0
Total	1410	220	4

of the infected tubers developed late-blight-infected shoots. It should be noted that the percentage of infected shoots that developed in this experimental plot probably was considerably higher than would develop from tubers planted in commercial fields, where no precautions are taken to eliminate other rots from the late-blight-infected tubers.

The writers realize fully that late blight may sometimes develop from planting dry-rot seed potatoes. However, the data presented here as well as our general observations indicate that the planting of diseased tubers by farmers seems not to be the most important source of the primary late-blight infection in Maine.

Murphy and McKay (12, p. 415) working in Ireland state that shallow planting of the infected seed pieces favors the growth of the fungus up the young sprouts to the surface of the soil. In the Maine experiments, however, the late-blight tubers were planted deep and were covered with a high ridge of soil as is the common practice in this State. It is quite possible that more infected plants would have resulted if the seed had been planted shallowly and covered with less soil than is the custom.

REFUSE PILES AS A SOURCE OF PRIMARY INFECTION

A potato inspector in 1935 called the writers' attention to a local late-blight epidemic which had occurred in the vicinity of a potato refuse pile located in central Aroostook County. Inspection

Fig. 2. Potato plants severely infected with late blight, in a refuse pile located at a secluded and hidden place on a farm. The disease is disseminated from such infected refuse piles to nearby potato fields.

on July 15 showed that the refuse pile was badly infected with late blight and that the conidia were being formed in large numbers.

The disease obviously had already spread from the infected refuse pile to an unsprayed potato field located approximately 200 feet away. The plants nearest the refuse pile were nearly all infected but the prevalence of the disease decreased as the distance from the pile increased and no blight spots or very few were found on plants 500 and 600 feet away. The disease also was present chiefly in the path of the winds from the southeast, which in this region are often moist or rain-bearing.

The information secured in 1935 aroused the authors' interest in the role that the potato refuse piles might have in the dissemination of late blight in Maine and further evidence was accumulated (4, pp. 293-294).

During the five-year period from 1937 to 1941 extensive surveys were made in Aroostook County to secure information on the prevalence of late blight in potato refuse or "dump" piles. Data were secured also regarding the spread of the disease from these primary sources of infection. The surveys each year were made during the period from June 20 to July 10 which was before most Aroostook farmers had begun to spray or dust.

The findings secured from the surveys are summarized in Table 2.

The data in Table 2 show that late blight often develops on the potato plants growing in the cull piles during the early part of the

TABLE 2

Summary of late blight infection occurring in potato refuse piles during the period from June 20 to July 10 in the years 1937 to 1941

Year	Refuse piles inspected		
	Total number	Number infected	Number from which spread to fields had evidently occurred
1937	95	75	15
1938	102	54	10
1939	150	83	18
1940	56	14	5
1941	14	6	4

growing season, before most growers have begun to spray. Figures 1, 2, and 3 show typical dump piles similar to those that were found in the surveys. Figures 4 and 5 show fields that were badly infected with late blight evidently as a result of spread from refuse piles.

Fig. 3. Late blight in potato plants growing in a refuse pile near a potato field. Late blight was noted in this refuse pile June 17, 1942. The badly blighted field shown in figure 4 resulted from late blight spores which were carried by the wind from this refuse pile.

Fig. 4. Field badly infected with late blight as a result of spread of the disease from the infected refuse pile shown in figure 3.

The late-blight spores (conidia) which develop in great numbers in the refuse piles may be carried by the prevailing winds to the neighboring fields and infect the young potato plants before the farmers have begun to spray. Early field infections spread rapidly when the weather conditions are favorable and epidemics may thus occur. Figure 6 shows a center of late-blight infection in a potato field which originated from a single small infection on a plant earlier in the season. The data in Tables 1 and 2 indicate that early field infection originates more frequently from the infected plants in refuse piles than from diseased seed tubers planted in the fields.

The question naturally arises as to why dry-rot tubers when planted in the field often do not develop diseased plants while those in the dump piles frequently are infected. One reason for this is that the conditions in the cull piles are more nearly ideal for the development of the disease because a dense mass of potato vines develops which remains moist and humid for long periods of time. A single small source of infection spreads rapidly under these conditions, liberating large numbers of conidia. Under normal field conditions the diseased shoots often die before secondary infections can occur. Also large numbers of infected tubers are concentrated in these cull piles. They sometimes may contain several hundred barrels of potatoes, many of which are infected with the disease. Furthermore the lack of soil covering over infected tubers at or near the surface of the pile favors emergence and exposure of young shoots to late-blight infection.

DISSEMINATION OF LATE BLIGHT FROM REFUSE PILES

Studies in 1938. To secure more detailed information regarding the spread of late blight from an infected dump pile, approximately 25 barrels of cull potatoes were deposited during the months of April and May, 1938, in a pile about 100 feet from a potato field. Late blight was first noted in this cull pile on June 15 and by June 25 the plants were badly infected. Aroostook County then experienced a week of cloudy weather which was followed by a gentle wind and rain from the southeast. On July 12, records were taken of the prevalence of late blight in the potato field at

different distances from the infected refuse pile. The results of these observations are summarized in Table 3.

Fig. 5. Field badly infected with late blight as a result of spread of the disease from a nearby infected refuse pile.

TABLE 3

Late blight in field at different distances from infected refuse pile—July 12, 1938

Distance from primary source	Plants infected	Lesions per 100 plants
Feet	Per cent	Number
100	98	293
200	55	98
300	21	31
400	6	9
500	0	0
600	1	1

These data show clearly that the infection was more abundant in closer proximity to the infected refuse pile. The disease obviously had been carried from the infected dump pile to the potato plants in the field. Spraying at weekly intervals began July 15. The spread of late blight was retarded, but by no means prevented, by the spraying operations.

FIG. 6. Center of late blight infection in a potato field. This large spot was observed to develop from a single small infection which could have resulted from a single late blight spore probably brought in by the wind from an infected refuse pile or from a neighboring field.

Studies in 1942. Additional data regarding the dissemination of late blight from potato refuse piles were secured in 1942. The disease was already present in one refuse pile when examined on June 8. At this time many stems and leaves were killed by late blight, indicating that initial infection occurred at least 2 weeks before June 8, or during the latter part of May. This (June 8) is the earliest calendar date that the disease has been found by the writers under natural conditions in northeastern Maine. Visits made a week later to other dumping places showed that the disease was present at these also. From July 5 until July 10 five fields in the vicinity of infected dump piles were examined for the presence of late blight. The data obtained from these observations are summarized in Table 4, and confirm the findings of previous years,

TABLE 4

Field development of late blight at different distances from infected refuse piles in 1942, as expressed in percentage of hills diseased early in July

Field number	100 ft. or less	100–200 ft.	300–400 ft.	500–600 ft.	Over 600 ft.
	Per cent	Per cent	Per cent	Per cent	Per cent
1	23	5	1	2	0
2	40	8	0	0	0
3	56	7	0	0	0
4	19	3	0	0.5	0
5	83	15	4	Trace	0

that the earliest field infections are most prevalent in close proximity to infected dump piles. The number of infected plants decreased as the distances from the cull piles increased and no infection was found more than 600 feet from the primary source of the disease. Figure 7 shows a close-up view of badly infected potato plants 100 feet from an infected refuse heap and in the path of the prevailing moisture-carrying winds. Figure 8, in contrast, shows healthy plants in the same field 600 feet from the infected dump pile but not in the path of the prevailing moist winds. Both photographs were taken July 21, 1942. It was noted also that the spread of the disease was mostly in one direction, namely, toward the northwest which would indicate that the late-blight conidia had been carried by winds from the southeast.

Farmers rarely notice the few scattered earliest infected leaves in their fields which have originated from the spread from the dump pile. From these small unnoticed initial points of infection, the disease spreads to the nearby plants and in about ten days a rather large blighted area is apparent in the field. It is at this stage of an epidemic, when large blighted spots are present in their fields, that the farmers generally take notice and begin to spray in earnest. It is then too late for the most efficient use of the spray material, and is like attempting to put out a fire after it is well started.

WIND DISSEMINATION OF LATE BLIGHT

Since the thin-walled spores of the late-blight fungus, as well as the swarm spores or zoospores, perish quickly in dry air and sunlight, it is often suggested that wind dissemination of these spores may not be an important factor. However, drifting mist and fog and wind-blown rains occurring in humid regions are favorable agents for dissemination of late blight spores and for infection.

There appears to be no doubt that the late-blight fungus is wind borne from dump piles to fields, from one plant to another in the same field, and from one field to another. In Aroostook County, late blight, when first observed in the field, generally appears as isolated small spots on the top leaves or stems of the potato plants, indicating that single conidia have been brought in from a distance. Generally the disease appears in this way at about the same time in a number of fields distributed over a large area, and this also indicates wind dissemination. Furthermore, the writers have caught conidia, apparently of the late-blight fungus, on adhesive-coated glass slides placed at 1,000 feet or more from the nearest potato field.

Every year late blight infects potato plants being grown from blight-free tubers in the Aroostook Farm greenhouse or under insect proof cages in the field. In an experiment conducted in 1927 (2, p. 105) the disease infected a potato plant that was grown in sterilized soil in a cloth covered cage having a solid wooden bottom. The late-blight conidia apparently had been brought from some

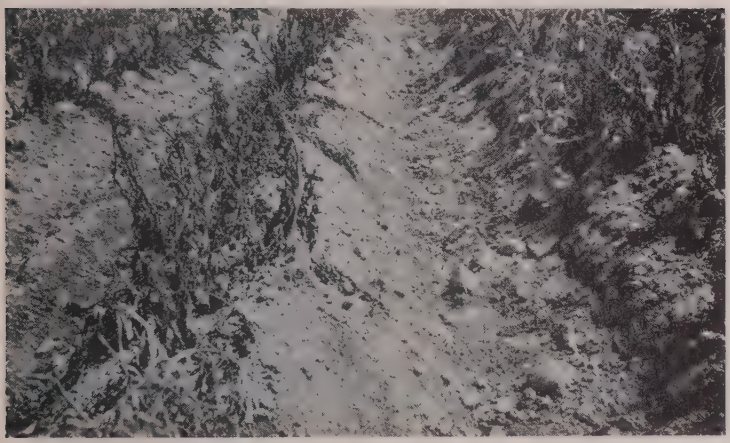

Fig. 7. Close-up view of plants approximately 100 feet from an infected refuse pile and in the path of the prevailing moisture-carrying winds. Notice that even at this early date, July 21, 1942, the plants were almost completely destroyed by late blight.

Fig. 8. Close-up view of plants in same field as those shown in figure 7 but 600 feet from infected refuse pile and not in the path of prevailing moisture-carrying winds. Notice that these plants are free from late blight at this early date, July 21, 1942. Later in the season the blight spread throughout the entire field.

distance by the air currents and were washed through the cloth cover into the cage by rain water.

A late-blight epidemic which was created for experimental purposes in 1936 affords some information about the spread of the disease by air currents (3, pp. 232-233). Fifty infected leaves were brought to the laboratory on July 18 and the spores washed off into a pail of rain water and then sprinkled onto an acre of unsprayed potatoes. The weather was moist but too cool for rapid development of the disease, and the symptoms of infection did not appear until July 24.[4] A misty rain and fog accompanied by a wind from the southeast prevailed for several days after the spores had developed. These conditions favored infection of nonsprayed young Green Mountain foliage in an adjacent field. Practically every plant for a distance of 500 feet from the southeast border of the field became infected with late blight. The disease was absent in the unsprayed fields located in other directions and was not found in fields that had been sprayed just prior to July 24.

This infected field was thereafter sprayed frequently. That part of the field which was first infected yielded at the rate of only 71 barrels or about 195 bushels per acre while another part of the field not first infected with late blight yielded at the rate of 147 barrels or 404 bushels per acre (3, p. 233). This was in accord with the amount of disease developing in the two parts of the field and was not explainable on the basis of any other factor such as difference in soil type. The loss thus caused by the disease was 76 barrels or 209 bushels per acre which is comparable to the losses often experienced by potato farmers when the disease is severe.

Late blight is by no means the only disease known to be disseminated by air currents. Craigie (6) gives a partial review of the literature relevant to aerial dissemination of plant pathogens. He cites evidence to show that many have astonishingly prolific reproductive ability and are dependent on air movements for their dispersal. He furnishes further evidence that the organisms responsible for stem rust of cereals, leaf rust of wheat, and crown rust of oats, as well as the causal organisms of kernel smudge of

[4] Under favorable conditions very small spots of infection resembling those of early blight generally appear about 72 hours after the plants have been inoculated and spores are produced on these spots after another period of 72 hours.

cereals, are air borne and that some spores may be carried several hundred miles from their place of origin.

Potato late blight is caused by a downy mildew fungus. Certain other downy mildew diseases are also known to be disseminated by winds. Weston (15, p. 265) observed that the spread of downy mildew of corn in the Philippine Islands followed closely the direction of nightly air currents. He showed further that the number of conidia produced by a single infected corn plant, even during one night, is exceedingly great, from about 758 million to nearly 6 billion (15, p. 262).

According to Newhall (13) perennial onions grown in back yards or farm gardens often are diseased with downy mildew of onion in June before commercial fields have the disease and in some seasons at least are a distinct menace to the onion industry of New York State. He cites a case where this disease had spread 3,300 feet from an infected plot of onion bulbs. Newhall caught viable conidia in the air over diseased onion fields to a height of 1,500 feet and concludes that the disease is wind borne and that infected perennial top-set and multiplier onions may serve as the primary source of the disease.

Downy mildew (blue mold) of tobacco also is wind borne for long distances according to a number of investigators (1, 5, 8, 9, and 10). Downy mildew of cucurbits apparently overwinters in Florida and is carried northward gradually from planting to planting by the aid of the wind to Georgia (14) and even to Massachusetts (7).

ELIMINATION OF REFUSE PILES

Potato growers always will have a problem of disposing of the cull potatoes which accumulate in the process of preparing the crop for market. Many farmers realize that cull piles are a menace to the potato industry, but have no definite information as to the most satisfactory method of eliminating this menace.

Some growers have destroyed the plants in their cull piles by pulling, cutting down, or digging out all of the growing plants. This requires frequent inspections to be certain that all the plants have been killed and in many cases this method has not been successful. Other growers spray their dump piles thoroughly with

Bordeaux or a blue vitriol solution to control the infection. Still others spread a thick layer of straw over the refuse pile and then set it on fire. The latter method appears to meet the approval of quite a few potato growers in Maine. It is possible that herbicides can be found that will be useful for the killing of potato plants in the refuse or cull pile.

Although diligent attention to control of late blight on dump piles by following the foregoing methods is possible, experience has shown that the average grower frequently fails to destroy the tops before infection has spread to adjoining potato fields. In view of the difficulty of destroying potato tops on dump piles, it would be much better not to deposit waste potatoes at all. In other words, not to set the house on fire is better than to start the fire and then devise means to put it out. Disposing of waste potatoes by boiling, burning, incineration, or feeding to livestock will prevent development of infected plants and the subsequent job of spraying or destroying such tops.

DISCUSSION OF RESULTS

The data presented in this study show that the potato refuse or cull pile is probably the chief source of the primary late-blight infection in Maine, and that its elimination would be a big factor in reducing the losses from late blight not only in Maine but in other States as well.[5] The possibility exists, however, that some late-blight infection may come also from the States located farther south and gradually be carried by the air currents from crop to crop northward into Maine in a manner similar to that described by Doran (7) and Van Haltern (14) for the spread of downy mildew of cucurbits.

On most of the 6,000 potato farms in Aroostook County as well as in the yards of many potato dealers there are one or more refuse piles where cull potatoes are discarded each spring. Many of these cull piles become infected with late blight and serve as the primary sources of late-blight inoculum for commercial fields. A single infected cull pile may serve to infect all of the potatoes being

[5] The senior writer while in the South in 1937 saw two cases where the late-blight fungus was sporulating profusely on a heap of discarded seed pieces which were near fields of potatoes.

grown in a locality. In one case, observed in 1942, late blight had spread to fields half a mile away in the direction of the prevailing winds.

The cull pile also is a place where the Colorado potato beetle and other insects multiply in great numbers. They migrate from here to nearby potato fields where they may cause much damage and add to the expense of growing the crop. Plants with leafroll, spindle tuber, and the mosaic diseases are found growing commonly in the cull piles and aphids generally are present to serve as vectors of these virus diseases to the commercially grown potatoes in the vicinity. Eliminating the cull piles not only would help to control late blight but also would be a factor in the destruction of certain harmful potato insects. It also would be helpful in destroying a likely source of spread of potato virus diseases.

SUMMARY

Late blight of potato still causes large losses in Maine in spite of the extensive spray program being conducted by the farmers for its control.

A study was conducted for the purpose of determining the primary source of infection in Aroostook County, Maine. The writers have found only one case where late blight in a field had originated from a diseased seed tuber which had been planted.

Attempts to create late-blight epidemics by planting diseased seed tubers have failed.

Surveys made over a period of five years have shown that late blight often develops early in the season on plants growing in potato refuse piles and from there is disseminated by air currents to nearby fields before the farmers have begun to spray.

It is concluded that the refuse or cull pile is the chief source of primary late-blight infection and that the elimination of this source of infection would do much to prevent the spread of the disease. Methods of destroying the refuse piles are being tried.

Burning or incinerating waste potatoes is recommended as a much better method of disposal than discarding them on a dump pile.

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